Claims

1. *(Original)* A magnetically-coupled structure in a magnetic device of the type having a substrate and a plurality of ferromagnetic layers, the structure being formed on the substrate and comprising:

a first ferromagnetic layer having an in-plane magnetization direction oriented in a first direction;

a second ferromagnetic layer magnetically-coupled to the first ferromagnetic layer and having an in-plane magnetization direction oriented substantially orthogonal to said first direction in the absence of an applied magnetic field; and

an electrically-conducting spacer layer between the first and second ferromagnetic layers, the spacer layer inducing substantial orthogonal magnetic coupling of the second ferromagnetic layer to the first ferromagnetic layer.

2. *(Original)* The structure of claim 1 wherein the spacer layer is an alloy comprising X and Mn, wherein X is selected from the group consisting of Pt, Ni, Fe, Ir, Pd and Rh.

3. *(Original)* The structure of claim 2 wherein the XMn alloy includes one or more elements selected from the group consisting of Cr, V, Pt, Pd and Ni.

4. *(Original)* The structure of claim 2 wherein the spacer layer is a PtMn alloy having a thickness less than approximately 100 Angstroms.

5. *(Original)* The structure of claim 4 wherein the PtMn alloy has a thickness between approximately 15 and 50 Angstroms.

6. *(Original)* The structure of claim 4 wherein the PtMn alloy comprises a PtMn alloy with Pt between approximately 25 and 75 atomic percent.

7. *(Original)* The structure of claim 1 wherein the spacer layer consists essentially of Cr or Mn.

8. *(Original)* The structure of claim 1 wherein the spacer layer consists essentially of a rare-earth transition-metal alloy selected from the group consisting of TbFe, TbCo, GdFe and GdCo.

9. *(Original)* The structure of claim 1 wherein the spacer layer consists essentially of a transition-metal alloy selected from the group consisting of Cu, Ru, Rh, Ir and Os.

10. *(Original)* The structure of claim 1 further comprising an antiferromagnetic layer exchange-coupled with the first ferromagnetic layer for substantially preventing rotation of the magnetization of the first ferromagnetic layer in the presence of an applied magnetic field.

11. *(Original)* The structure of claim 1 wherein the first ferromagnetic layer is a hard ferromagnet having a magnetization direction substantially prevented from rotation in the presence of an applied magnetic field.

12. *(Original)* The structure of claim 1 wherein the device is a current-perpendicular-to-the-plane magnetoresistive sensor and wherein the second ferromagnetic layer is the sensor free layer whose magnetization direction is free to rotate in the presence of an applied magnetic field, the magnetization of the free layer being stabilized across the spacer layer by the first ferromagnetic layer.

13. *(Original)* A magnetoresistive sensor capable of sensing external magnetic fields when a sense current is applied perpendicular to the planes of the layers in the sensor, the sensor comprising:

a substrate;

a free ferromagnetic layer having an in-plane magnetization direction oriented substantially in a first direction in the absence of an external magnetic field, said free layer magnetization direction being substantially free to rotate in the presence of an external magnetic field;

a pinned ferromagnetic layer having an in-plane magnetization direction oriented in a second direction substantially orthogonal to said first direction;

a first antiferromagnetic layer exchange-coupled to the pinned layer and preventing substantial rotation of the magnetization direction of the pinned layer in the presence of an external magnetic field in the range of interest;

a nonmagnetic spacer layer between the free and pinned layers;

a ferromagnetic biasing layer magnetically-coupled to the free layer and having an in-plane magnetization direction oriented substantially orthogonal to said first direction in the absence of an external magnetic field; and

an electrically-conducting spacer layer between the biasing and free layers, the spacer layer between the biasing and free layers inducing substantial orthogonal magnetic coupling of the free layer to the biasing layer.

14. *(Original)* The sensor of claim 13 further comprising a second antiferromagnetic layer exchange-coupled with the biasing layer for substantially preventing rotation of the magnetization direction of the biasing layer in the presence of an external magnetic field in the range of interest.

15. *(Original)* The sensor of claim 13 wherein the biasing layer is a hard ferromagnet having a magnetization direction substantially prevented from rotation in the presence of an external magnetic field in the range of interest.

16. *(Original)* The sensor of claim 13 wherein the nonmagnetic spacer layer is electrically conducting.

17. *(Original)* The sensor of claim 13 wherein the sensor is a magnetic tunnel junction and wherein the nonmagnetic spacer layer is an electrically-insulating tunnel barrier.

18. *(Original)* The sensor of claim 13 wherein the pinned layer is located between the substrate and the free layer and the free layer is located between the pinned layer and the biasing layer.

19. *(Original)* The sensor of claim 13 wherein the pinned layer is an antiparallel-pinned layer.

20. *(Original)* The sensor of claim 13 wherein the sensor is a magnetoresistive read head for reading magnetically recorded data from tracks on a magnetic recording medium, wherein the substrate is a first shield formed of magnetically permeable material and having a substantially horizontal planar surface, wherein the free and pinned layers and nonmagnetic spacer layer have substantially vertical side walls defining a sensor trackwidth less than the width of the first shield, and wherein the biasing layer is on the substrate beneath the free layer and extends beyond the sensor trackwidth.

21. *(Original)* The sensor of claim 19 wherein the electrically-conducting spacer layer between the biasing and free layers is on the biasing layer and extends beyond the sensor trackwidth.

22. *(Original)* The sensor of claim 13 wherein the spacer layer between the biasing and free layers is an alloy comprising X and Mn, wherein X is selected from the group consisting of Pt, Ni, Fe, Ir, Pd and Rh.

23. *(Original)* The sensor of claim 22 wherein the spacer layer between the biasing and free layers is a PtMn alloy having a thickness less than approximately 100 Angstroms.

24. *(Original)* The sensor of claim23 wherein the PtMn alloy comprises a PtMn alloy with Pt between approximately 25 and 75 atomic percent.

25. *(Original)* The sensor of claim 13 wherein the spacer layer between the biasing and free layers consists essentially of Cr or Mn.

26. *(Original)* The sensor of claim 13 wherein the spacer layer between the biasing and free layers consists essentially of a rare-earth transition-metal alloy selected from the group consisting of TbFe, TbCo, GdFe and GdCo.

27. *(Original)* The sensor of claim 13 wherein the spacer layer between the biasing and free layers consists essentially of a transition-metal alloy selected from the group consisting of Cu, Ru, Rh, Ir and Os.

28. *(Original)* A current-perpendicular-to-the-plane magnetoresistive read head for reading magnetically recorded data from tracks on a magnetic recording medium, the head comprising:

a first shield of magnetically permeable material and having a substantially horizontal planar surface;

a ferromagnetic biasing layer on the first shield and having an in-plane magnetization direction oriented in a fixed direction in the absence of a magnetic field from the medium;

an electrically-conducting magnetically-coupling layer on the biasing layer;

a free ferromagnetic layer on the magnetically-coupling layer and magnetically-coupled across the magnetically-coupling layer to the biasing layer, the free layer having an in-plane magnetization direction oriented approximately orthogonal to the fixed magnetization direction of the biasing layer in the absence of a magnetic field from the medium and substantially free to rotate in the presence of a magnetic field from the medium;

a nonmagnetic spacer layer on the free layer;

a pinned ferromagnetic layer having an in-plane magnetization direction parallel to the fixed magnetization direction of the biasing layer;

an antiferromagnetic layer exchange-coupled to the pinned layer and preventing substantial rotation of the magnetization direction of the pinned layer in the presence of a magnetic field from the medium; and

wherein the free and pinned layers and nonmagnetic spacer layer have substantially vertical side walls defining a sensor trackwidth less than the width of the first shield, and wherein the biasing layer extends beyond the sensor trackwidth.

29. *(Original)* The head of claim 28 wherein the magnetically-coupling layer extends beyond the sensor trackwidth.

30. *(Original)* The head of claim 28 further comprising an antiferromagnetic layer between the first shield and the biasing layer and exchange-coupled with the biasing layer for substantially preventing rotation of the magnetization direction of the biasing layer in the presence of a magnetic field from the medium, the antiferromagnetic layer exchange-coupled to the biasing layer extending beyond the sensor trackwidth.

31. *(Currently amended)* The head of claim ~~23~~ 30 wherein the antiferromagnetic layer exchange-coupled to the biasing layer is formed of a material selected from the group consisting of PtMn, NiMn, FeMn, IrMn, PdMn, PdPtMn and RhMn.

32. *(Original)* The head of claim 28 wherein the head is a spin-valve head and the nonmagnetic spacer layer is electrically-conducting.

33. *(Original)* The head of claim 28 wherein the head is a magnetic tunnel junction head and wherein the nonmagnetic spacer layer is a tunnel barrier.

34. *(Original)* The head of claim 28 wherein the magnetically-coupling layer is an alloy comprising X and Mn, wherein X is selected from the group consisting of Pt, Ni, Fe, Ir, Pd and Rh.

35. *(Original)* The head of claim 34 wherein the XMn alloy includes one or more elements selected from the group consisting of Cr, V, Pt, Pd and Ni.

36. *(Original)* The head of claim 34 wherein the magnetically-coupling layer is an alloy comprising Pt and Mn and having a thickness less than approximately 100 Angstroms.

37. *(Original)* The head of claim 36 wherein the PtMn alloy has a thickness between approximately 15 and 50 Angstroms.

38. *(Original)* The head of claim 36 wherein the PtMn comprises a PtMn alloy with Pt between approximately 25 and 75 atomic percent.

39. *(Original)* The head of claim 28 wherein the magnetically-coupling layer consists essentially of Cr or Mn.

40. *(Original)* The head of claim 28 wherein the magnetically-coupling layer comprises rare-earth transition-metal alloy selected from the group consisting of TbFe, TbCo, GdFe and GdCo.

41. *(Original)* The head of claim 28 wherein the magnetically-coupling layer consists essentially of a transition-metal alloy selected from the group consisting of Cu, Ru, Rh, Ir and Os.